CHAPTER NINE

An International Comparison of Transportation and Air Pollution

Mobile sources account for a significant share of urban air quality problems worldwide. Motor vehicles are a major source of carbon monoxide (CO), nitrogen oxides (NO_X), and volatile organic compounds (VOC) emissions in all advanced industrial countries. In developing countries, despite lower levels of transportation-related air pollutant emissions on a national basis, many mega-cities have severe air quality problems from the increased use of cars and trucks and the limited use of emissions controls. In all countries, of course, industrial and other emissions from stationary sources also affect urban air quality.

Moreover, the large quantities of gasoline and diesel fuel consumed by the transportation sector raise concerns about the addition of carbon dioxide (CO_2), a greenhouse gas, to the atmosphere and its potential for global climate change. The United States and other industrialized countries account for 65 percent of mobile source greenhouse gas emissions. Developing countries' contributions, however, are expected to grow appreciably in the future as per capita use of highway vehicles increases in these nations.

There were over 615 million motor vehicles in the world fleet in 1993, and rapid growth is expected. How this growth affects air quality and the global climate is drawing attention.

Air pollutants do not respect geographic or political borders: the more that is learned about emissions, the harder it is to identify impacts that are purely local in nature. Lead, for example, has been found thousands of kilometers from its source. Thus, transportation-related air pollution is increasingly debated at the international level.

Important lessons can be learned by evaluating other countries' experiences in dealing with transportation-related environmental issues. Although pollution control strategies may be site specific, understanding their strengths and weaknesses can be helpful in adapting them for use elsewhere. In addition, sharing information about air pollution trends can contribute to improvements in measurement techniques.

This chapter focuses on international trends in air pollution from motor vehicle use—the transportation mode for which the most information is available. It presents emissions data (principally, for CO, VOC, NO_x and CO_2) for Organization for Economic Cooperation and Development (OECD) countries,[1] including the United States, France, the United Kingdom, Japan, and western Germany).[2] The chapter also discusses motor vehicle trends affecting air quality in non-OECD countries, although the information is much more limited. The chapter often uses the generic term "developing countries" to refer to non-OECD countries, although the state of economic development among this group varies widely. Where possible, this chapter follows the often-used convention of categorizing the diverse countries of the world as low-, lower middle-, upper middle-, and high-income economies. When the data permits, information about the former East Bloc (FEB) countries in Eastern Europe and the former Soviet Union is provided separately. Otherwise, FEB data is included with non-OECD countries.

This chapter is divided into four sections, beginning with a discussion of global trends in motor vehicle use. The second section provides a comparative discussion of some motor vehicle emissions in key OECD countries. Section three covers non-OECD countries. The final section discusses CO_2 emissions from transportation in both OECD and non-OECD countries.

Conventional air emissions from motor vehicles are a major but, by no means, the only important environmental effect of transportation. A comprehensive international comparison would examine transportation's contributions to other forms of hazardous air pollution.[3] It would also need to examine other modes of transportation (comparing modal shares of transport by country) and other important direct and secondary impacts of transportation activities, such as contributions to water pollution, impacts on land use and habitat modification, and natural resource issues. This broader array is beyond the scope of this chapter.

Global Trends in Motor Vehicle Use and Emissions

The impact of motor vehicles on air quality depends on many factors. These include, among others, the number of vehicles in use; how far and how fast they are driven; road traffic volume; the kind and extent of use of emissions controls; what kind and how much fuel is used; and the local climate and topography. These fac-

[1] OECD is an intergovernmental organization founded in 1960. Its primary goal is to promote economic policies that stimulate growth, employment, and the expansion of trade among its members. The organization's current member countries are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States. Mexico joined OECD in 1994. As most of the data in this chapter predates 1994, statistics for Mexico, when available, are included here with non-OECD data.

[2] Germany is referred to as "western Germany" in this chapter because the trend data used for analysis covers only what was, prior to reunification in 1991, West Germany.

[3] Lead, covered here, can be classified as a hazardous air pollutant. So are many VOCs. For example, benzene is a carcinogen. Particulate matter can also contain carcinogens.

tors interact in complex ways that complicate international comparisons.

The very rapid worldwide growth in the number of motor vehicles and in road traffic has prompted considerable concern about air quality impacts. The number of motor vehicles in the world more than doubled in the last two decades (see figure 9-1). In 1993, the world fleet consisted of 469 million passenger cars and 148 million freight vehicles.[4] (OECD 1995b, 215–219) Between 1970 and 1993, the average annual increase in the number of motor vehicles was 2.6 percent in the United States, 4.4 percent in other OECD countries, and 6.5 percent in the rest of the world (see table 9-1). The U.S. share of the world's motor vehicle fleet decreased from 44 percent in 1970 to 31 percent in 1993.

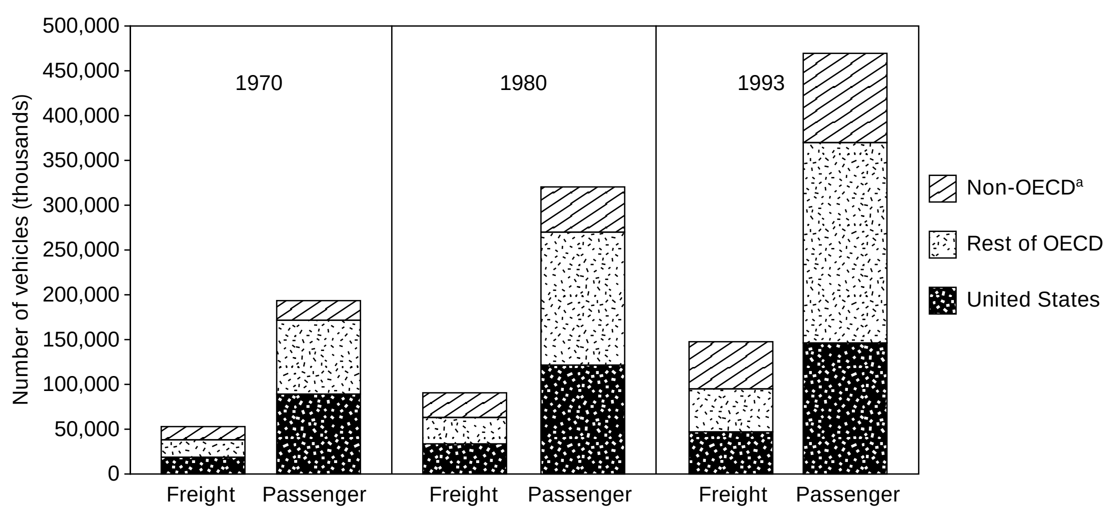
During the same period, the share of the world's motor vehicle fleet held by non-OECD countries increased from 14 to 24 percent. Previously used vehicles imported from OECD countries account for much of the fleet growth in these countries. (Michaelis et al 1996)

Of the 1993 stock of passenger cars, 81 percent were in OECD countries. Per capita car ownership in developing countries is still far below that in OECD countries. While there are two to three people for every car in many OECD countries, in low-income countries, such as Nigeria and Pakistan, there are more than 100 people per car. In China, there were 616 people for every car in 1992. If some Asian countries continue to sustain high rates of economic growth, however, explosive rates of motorization could result. An OECD report suggests the global fleet could exceed 800 million units by 2000. (OECD 1995c, 38)

Road traffic growth reflects, among other things, the combined effects of growth in population, gross domestic product (GDP) per capita, and the number of vehicles per capita. For such OECD countries as the United States, France, and

[4] Unless otherwise specified, motor vehicles include passenger cars, trucks, buses, coaches, and other road vehicles with at least four wheels.

FIGURE 9-1: PASSENGER AND FREIGHT VEHICLES, 1970–93



[a] Includes Mexico 1970–93.

SOURCE: Organization for Economic Cooperation and Development, *OECD Environmental Data: Compendium 1993;* and *OECD Environmental Data: Compendium 1995* (Paris, France: 1993 and 1995).

TABLE 9-1: WORLD MOTOR VEHICLE FLEET, 1970–93

Country or region	1970: Number of vehicles (thousands)	1993: Number of vehicles (thousands)	Shares of total (percent)		Annual growth rate (percent) 1970–1993
			1970	1993	
OECD	**211,686**	**469,233**	**86**	**76**	**3.5**
United States	108,418	194,063	44	31	2.6
Other OECD	103,268	275,170	42	45	4.4
Non-OECD	**34,692**	**147,854**	**14**	**24**	**6.5**
Total (world)	246,378	617,087	100	100	4.1

NOTE: Data for Mexico are included with non-OECD data.
SOURCES: Organization for Economic Cooperation and Development, *OECD Evironmental Data: Compendium 1993* (Paris, France: 1993), p. 221; and *OECD Environmental Data: Compendium 1995* (Paris, France: 1995), p. 215.

the United Kingdom, traffic growth also reflects a greater intensity of car use. Table 9-2 compares road traffic volume for selected OECD countries for passenger and freight vehicles. Passenger vehicle road traffic volume grew much more rapidly between 1970 and 1993 than population and, in some cases, slightly faster than the growth in vehicle stock. Similarly, freight road traffic volumes grew faster than GDP for the same period. Similar trends occurred in some non-OECD countries. For example, Poland's road travel volumes increased from about 13 billion to 91 billion vehicle-kilometers (8 billion vehicle-miles traveled—vmt—to 56 billion vmt) from 1970 to 1991, for an annual growth rate of 9.7 percent. (OECD 1993a, 227) The International Energy Agency (IEA) reports that, in India, passenger-kilometers traveled by road increased significantly faster than GDP. (IEA 1995, 185)

OECD countries still account for over 70 percent of the world's driving. Major emissions control efforts in the United States, Japan, and several other countries have kept their share of several key pollutants lower than their share of vmt. OECD countries, however, still accounted for 48 percent of the CO, 59 percent of the VOC, and 64 percent of the NO_x emitted by the global motor vehicle fleet in 1990. (OECD 1995c)

Most developing countries (as well as many OECD countries) lag far behind the leaders in adopting and enforcing emissions control and cleaner fuel standards. The non-OECD countries share of emissions, especially VOC and CO, is out of proportion to their share of vehicle fleets and usage. Several non-OECD countries, however, are taking promising actions to address transportation needs in more environmentally sustainable ways.

OECD countries were responsible for 65 percent of the 1993 mobile source CO_2 emissions. For the previous two decades, OECD countries held a 70 percent share. The recent decline may signal a shift toward increasing shares by non-OECD countries. CO_2 emissions from FEB countries actually fell in the 1980s because of severe economic declines. Among other non-OECD countries, emissions grew 133 percent between 1971 and 1993. During the same period, OECD countries' emissions grew only 45 percent.

The United States is the world's largest contributor to CO_2 emissions from transportation. U.S. emissions grew more slowly than in other OECD countries where car ownership and annual highway travel are climbing closer to U.S. levels. The lower U.S. growth rate may have been partly driven by larger gains in passenger car fuel efficiency in the United States during this period.

TABLE 9-2: ROAD TRAFFIC VOLUME IN OECD COUNTRIES, 1970–93

PASSENGER CAR	Vehicle-km traveled (vkt) (billions)			Annual growth rates (percent)	
Country	**1970**	**1980**	**1993[a]**	**1970–93 vkt**	**Passenger cars 1970–1993**
United States	1,434	1,789	2,652	2.7	2.2
Japan[b]	120	241	429	6.5	6.9
France	165	245	343	3.2	3.0
Western Germany	216	297	425	3.0	3.6
Italy	123	191	356	4.7	4.8
Great Britain	141	197	334	3.8	3.2
Netherlands	38	61	81	3.4	3.8
OECD	2,584	3,604	5,473	3.3	3.4
FREIGHT	Vkt (billions)			Annual growth rates (percent)	
Country	**1970**	**1980**	**1993[a]**	**1970–93 vkt**	**Freight vehicles 1970–1993**
United States	346	619	1,039	4.9	4.1
Japan[b]	100	142	272	4.4	4.1
France[c]	32	49	94	4.8	3.9
Western Germany	37	32	46	3.6	2.0
Italy[d]	23	33	52	3.6	4.9
Great Britain	35	41	64	2.7	2.2
Netherlands	6	8	16	4.4	3.4
OECD	656	1,086	1,807	4.5	4.1

[a] Provisional data.
[b] Excludes light vehicles.
[c] Excludes freight vehicles over 15 years old with load capacity greater than or equal to 3 metric tons.
[d] Includes three-wheel vehicles.

SOURCE: Organization for Economic Cooperation and Development, *OECD Environmental Data: Compendium 1993,* and *OECD Environmental Data: Compendium 1995* (Paris, France: 1993 and 1995).

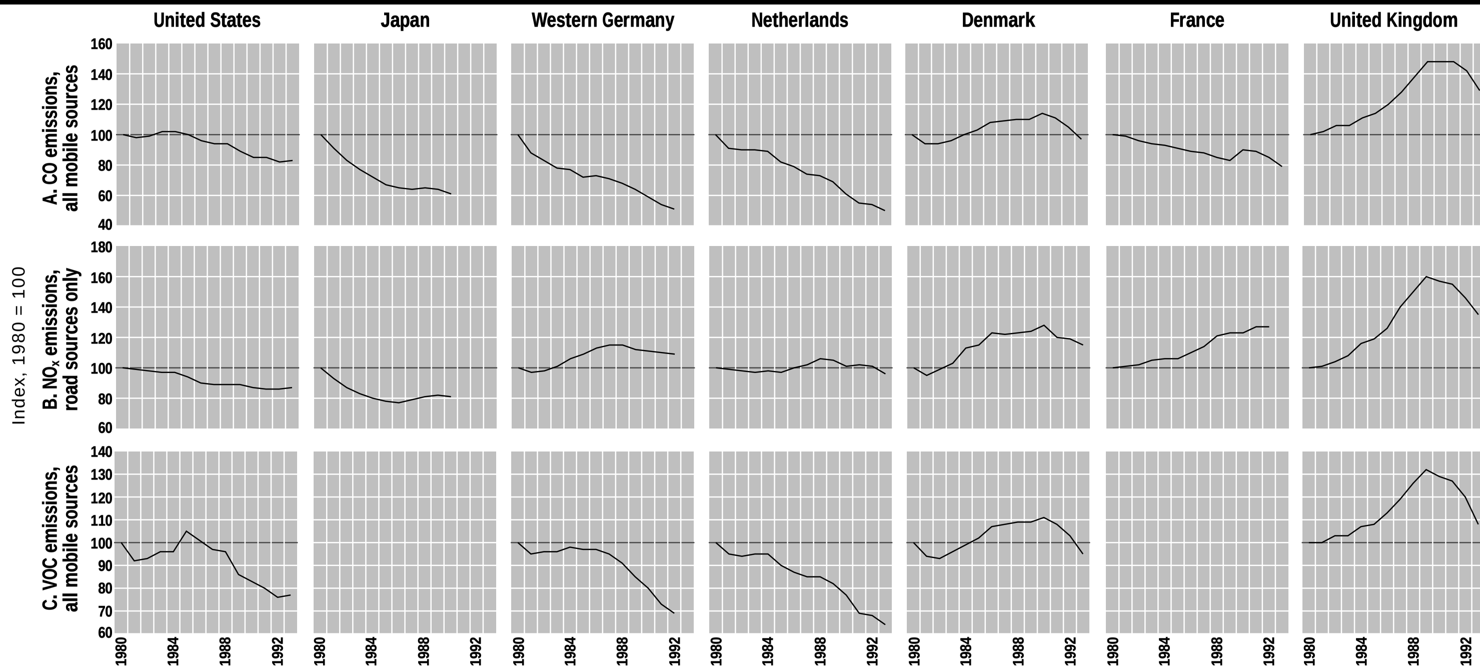
Air Emissions in OECD Countries

Despite more than 20 years of effort in combating emissions, air quality remains a problem in OECD countries.[5] In the summer of 1995, 16 pollution alerts were triggered by high ozone levels in Paris. In the United States, about 62 million people still lived in counties that failed to attain one or more national ambient air quality standards in 1994. Furthermore, while the United States has made much progress in reducing transportation-related air pollution, mobile sources still accounted for 78 percent of CO, 37 percent of VOC, and 45 percent of NO_X emissions in 1994.

Figure 9-2 shows how mobile source emissions of CO, VOC, and NO_X changed between 1980 and 1993 in several high-income OECD countries. It includes most European countries for which OECD has compiled relatively complete data covering these years and pollutants (western Germany, France, Denmark, the Netherlands, and the United Kingdom). The U.S. emissions data

[5] Unless otherwise noted, U.S. data in this section are based on USEPA 1995, and data for other countries are from OECD 1993a, OECD 1995b, and OECD 1995c.

FIGURE 9-2: MOBILE SOURCE AIR EMISSIONS IN SELECTED OECD COUNTRIES, 1980–93



KEY: CO = carbon monoxide; NO_x = oxides of nitrogen; VOC = volatile organic compounds.

NOTE: No data are available for VOC emissions in Japan and France.

SOURCES: U.S. data are from U.S. Environmental Protection Agency, *National Air Pollutant Emission Trends, 1900–1994,* EPA 454/R-95-011 (Research Triangle Park, NC: 1995); data for other countries are from Organization for Economic Cooperation and Development, *OECD Environmental Data: Compendium 1995* (Paris, France: 1995).

are from the most recent estimates published by the U.S. Environmental Protection Agency (EPA) for these years. (USEPA 1995) Trends for NO_x and CO emissions in Japan are also portrayed. Japan has been one of the most aggressive countries in controlling air pollution from cars, but the OECD data on Japan does not include all years in the time series, and does not include VOC.

The trend data should be interpreted cautiously, as there are differences among countries in the way emissions are measured. Although efforts to develop more consistent emissions data have been underway in Europe since 1985, the OECD data reported here are not necessarily internally consistent. (USEPA 1995, 7-1)

The OECD data for NO_x emissions are reported for highway vehicles alone. The OECD data for CO and VOC, however, cover all mobile source emissions. Countries may define mobile sources and collect data in different ways. The United States, as is discussed in chapter 7, includes many categories of nonroad sources in its mobile source data, including such nontransportation sources as lawn and garden equipment.

The timing and nature of control measures greatly influence emission trends. Most OECD countries have set emission standards for new vehicles. Some countries and cities have introduced a variety of other measures, as discussed in box 9-1. (U.S. programs are discussed in chapters 7 and 8).

There can be significant delays between promulgation of emission standards and actual implementation. For example, it was not until the 1981 model year that newly manufactured cars in the United States were required to fully meet emissions standards initially set for 1975 by the 1970 Clean Air Act. Japan, which had adopted standards similar to those in the United States, was the first country to produce new vehicles that met the initial standards. Several European countries set standards some years before fully implementing them in the late 1980s and early 1990s.

Other factors, such as the types of fuels in use and modal mix, also affect trends. Americans, for example, drive more than western Europeans, in part because of the large land area of the United States, the relatively low density of U.S. cities, and the more limited availability of alternatives to cars for urban travel. (OECD 1995d, 71) People in Japan drive less because of high-density cities, fewer highways, and metropolitan areas served by a well-developed rail system.

Of the countries in figure 9-2, the United States has one of the better records in curbing mobile source emissions. Despite rapidly growing freight and passenger transport, new passenger cars and light trucks in the United States today emit far less pollution than similar vehicles in the early 1970s (see chapters 7 and 8). Indeed, the majority of passenger car air pollution emissions in the United States today are produced by old and/or improperly maintained vehicles, or result from operation of vehicles under conditions not currently covered by current standards (see box 8-2 in chapter 8).

Although data are more limited, Japan also has had much success in curbing mobile source air pollutants. A 1994 OECD evaluation of Japan's environmental performance judged its success in meeting stringent emission requirements for automobiles as remarkable. (OECD 1994a, 123)

► CO Emissions

Transportation is the major source of CO emissions in OECD countries. In 1993, transportation's share of CO ranged from 64 to 92 percent in the countries shown in figure 9-2a. Most of these countries, however, have decreased transportation-related CO emissions over the last 15 years.

Despite increased road traffic, the United States lowered CO emissions from all mobile sources (including lawn and garden equipment) by 17 percent between 1980 and 1993. Some

Box 9-1: Transportation Approaches in Several European Cities

The growth in motor vehicle use in the urban areas of Europe has caused congestion and increases in air pollution. Some European cities are attempting to mitigate these problems with policies that seek to maintain or increase use of public transportation and nonmotorized transporation options and discourage motor vehicle use.

Milan introduced an emergency measure to improve air quality in 1990. It restricts vehicle use on days when the city's pollution levels exceed a reference level. Alternate day use restrictions have helped keep pollution levels below a second reference level that would trigger a prohibition. Complementing the car use policy, Milan has a program to improve and extend public transportation services.

Stockholm adopted a comprehensive transportation package in 1991. The agreement committed the three leading political parties to mitigation of environmental and congestion problems in the region over the next 15 years at a cost of about $4.6 billion. The plan is roughly divided between roads and public transport. It provides for more regional rail lines, track improvements, better coordination between services, and more park-and-ride facilities. The metro system is to be completely modernized and a new rapid tram line constructed around the inner city. Highway proposals are designed to improve accessibility while reducing car traffic in the city. A toll system will be used to steer traffic to peripheral routes. Only low-emissions vehicles will be allowed in the inner core area. Expectations are for a 25-percent reduction in traffic in the inner areas and a 50-percent reduction in air pollution. CO_2 emissions, however, will remain about the same.

In **Helsinki**, use of public transportation remains level although its share of total travel is diminishing. While the region is investing in roads to keep up with the growth in car ownership, a number of measures are helping to promote public transportation. Included are generous subsidies to keep fares low, dedicated bus and tram lines with priority at traffic signals, improved rail services and extensions to the metro system, and special easy-to-use ticketing and information systems. As a complement to these measures, parking is controlled in the city.

After years of planning, **Grenoble**, was able to increase public transportation use substantially as the city grew, but public transportation's modal share increased only modestly. Grenoble attempted an integrated approach to transportation that included highway planning, better public transportation, and more facilities for pedestrians and cyclists. Special bus lanes were designated, pedestrian precincts established, and an extensive cycleway program introduced. A new tramway system is complemented by measures to restrict parking and improve traffic circulation. Despite these measures, increases in road traffic may be eroding earlier reductions in noise and pollution.

SOURCE: Organization for Economic Cooperation and Development, European Conference of Ministers of Transport, *Urban Travel and Sustainable Development* (Paris, France: 1995), pp. 214–220.

other OECD countries with similar or higher growth rates in road traffic achieved larger percentage reductions during the same period. CO emissions decreased by 48 percent in western Germany and 50 percent in the Netherlands, for example. Emissions in Japan fell by 39 percent between 1980 and 1990.

In the United Kingdom, CO emissions rose by 29 percent over the 1980 to 1993 period, although improvement has occurred since 1989. The United Kingdom's poor performance on CO (and other) emissions probably can be attributed to the fact that it only recently required catalytic converters on new cars.

VOC Emissions

Among the six OECD countries in figure 9-2b, VOC emissions from mobile sources accounted for 33 to 41 percent of total VOC emissions in 1993. Transportation's share of VOC emissions was smaller in 1993 than it was in 1980 in these countries, with the exception of a slight increase in the United Kingdom.

Sharp declines in VOC emissions occurred in western Germany and the Netherlands between 1980 and 1993—31 and 36 percent, respectively. Emissions in the United States also declined appreciably—by 23 percent. Denmark's emissions declined 5 percent. The United Kingdom's VOC emissions rose 8 percent, although they began to decline after 1989.

NO_X Emissions

Figure 9-2c displays NO_X emissions trends for road transportation in eight countries. Road transportation is a more accurate measure of motor vehicle emissions than the broader mobile source category. Road transportation's 1993 share of all NO_X emissions in these countries ranged from 32 percent in the United States to 72 percent in France.

The control of NO_X emissions from transportation sources requires sophisticated catalytic technology (the three-way converter) and control measures. Japan and the United States were among the first to require such controls in new automobiles. Most European countries have been slower in adopting such requirements. The effect of this delay (and higher use of diesel fuels in Europe) shows in the trend lines in figure 9-2c.

The United States and Japan were the only countries in which road transportation's share of total NO_X emissions declined between 1980 and 1993. Elsewhere, road transportation's increased share reflects both increases in highway vehicle emissions and declines in stationary source emissions.

NO_X emissions have recently begun to increase even in Japan and the United States, however. In the United States, NO_X emissions from road transportation declined 14 percent between 1980 and 1991, before starting to rise again (by 2 percent) in subsequent years. Japanese road transportation emissions declined by 23 percent between 1980 and 1986, but rose by 6 percent in the following four years. Despite Japan's early achievement, large metropolitan areas in Japan have had difficulties in attaining full compliance because of truck emissions. (OECD 1994b)

Particulate Emissions

Countries measure particulate emissions in different ways. For example, the United States normally reports on PM-10, particulates of only 10 microns or less in diameter, because of their more likely health effects. Other countries may use the more inclusive measures, total suspended particulates (TSP) or suspended particulate matter (SPM).[6] Particulate emissions data may also include road dust from paved and unpaved roads.

Of the five countries reporting mobile source particulate emissions trend data to OECD, only the Netherlands showed a decline between 1980 and 1993. During the same period, the United States reported a 20 percent increase in TSP (while mobile sources of PM-10 declined by 1 percent). Western Germany, France, and the United Kingdom reported increases.

The increase in particulates in Europe may be explained partly by greater use of diesel fuel. Diesel engines without particulate controls emit much more particulate matter than gasoline-powered vehicles with catalytic converters that are fueled with unleaded gasoline. (World Bank 1995a, 34) Diesel fuel consumption increased at a much faster rate than gasoline consumption in

[6] To be consistent with the data sources used in this chapter, this section focuses on SPM or TSP rather than PM-10.

Europe. Most of the increase was for freight road transport, but the number of diesel passenger cars also increased. (OECD 1995d, 67) Diesel passenger car registrations in Europe increased from 14 percent of all car registrations in 1990 to 21 percent in 1993. Diesels account for less than 1 percent of U.S. passenger car registrations. (IEA 1995, 275) OECD countries in Europe consume about half of the diesel fuel attributed to OECD as a whole.

► Lead and Sulfur Dioxide Emissions

Lead and sulfur dioxide emissions occur when motor vehicle fuels contain sulfur or lead compounds. To reduce these emissions, some countries have set fuel content requirements that limit the amount of these materials in fuels.

Use of lead as a gasoline additive has declined because of health concerns and the introduction of catalytic converters, which malfunction when leaded gasoline is used. The amount of lead added to gasoline declined 75 percent worldwide from 1970 to 1993. Still, as late as 1989, gasoline combustion accounted for an estimated 62 percent of worldwide lead emissions. Leaded gasoline is still in wide use in many developing and in some OECD countries.

As table 9-3 shows, unleaded gasoline as a share of total gasoline consumption varies considerably by country. Among OECD countries, Japan, the United States, and Canada have either phased out leaded gasoline entirely or are very close to achieving complete phase out. According to the World Bank, the sharp reduction in lead content of fuels in many OECD countries has lowered lead levels in the bloodstream. (World Bank 1992) In the United States and Japan, average blood lead concentrations are now only one third of those reported in the mid-1970s. In 1993, however, leaded gasoline still commanded a substantial share of consumption in Spain, Italy, and New Zealand, and to a lesser extent in the United Kingdom, Australia, and France.

Table 9-3: Unleaded Gasoline as a Percentage of Motor Gasoline Consumption in Selected Countries, 1993

Country	Unleaded gasoline
Japan	100
Brazil	100
South Korea	100
Canada	100
United States	99
Germany	89
Netherlands	75
United Kingdom	53
Australia	45
France	41
Mexico	30
China [a]	30
New Zealand	30
Italy	24
Poland	12
Venezuela	10
Spain [a]	6
Russia	5
India [b]	0
Saudi Arabia	0
Nigeria	0

[a] Data for 1992.
[b] Introduced unleaded gasoline in 1995.

SOURCES: Organization for Economic Cooperation and Development, *Control of Hazardous Air Pollutants in OECD Countries* (Paris, France: 1995), p. 22; and Odil Tunali, "Lead in Gasoline Slowly Phased Out," *Vital Signs 1995: The Trends that are Shaping Our Future*, Lester Brown et al. (eds.) (New York, NY: W.W. Norton, 1995), p. 126.

SO_2 emissions from all mobile sources in OECD countries are generally far less than from stationary sources, such as industrial facilities and utilities. (OECD 1995b, 19–23) In some countries, nonroad mobile sources emit more SO_2 than road transportation. Among European countries reporting road transportation emissions over the period 1980 to 1993, SO_2 emissions increased in the United Kingdom (40 percent), while decreasing in western Germany (39 percent) and Denmark (71 percent). According to EPA data, SO_2 emissions in the United States declined slightly less than 1 percent between 1980 and 1993. (USEPA 1995, table A-4)

Air Pollution and Transportation in Non-OECD Countries

► Air Quality

Air pollution data, especially trend data about motor vehicle emissions, are not available for most non-OECD countries. Still, it is clear that air pollution is a significant problem in many developing countries where rapid economic growth has stimulated the consumption of fossil fuels in industry and transport. (World Bank 1995a, xi) Energy-intensive industries are growing as a proportion of their economies, and these countries, by and large, are only beginning to address their environmental problems.

Air pollution problems are acute in large cities in developing countries, where high population densities increase risk of exposure to pollution (see box 9-2). Air quality in the least polluted cities in low-income economy countries was, on average, worse than that of the most polluted cities in high-income countries. (World Bank 1992) Air quality problems are acute in Asia, which includes five of the seven cities in the world with the worst air pollution: Beijing, Calcutta, Jakarta, New Delhi, and Shenyang. (World Bank 1993, 11) About 26 percent of Latin America's urban population is exposed to dangerous levels of motor vehicle-related air pollution, according to the Pan American Health Organization.

Serious health risks arise from exposure to lead and SPM. Airborne lead poses serious health risks, especially where lead is still used as a fuel additive. The problem is particularly acute in towns and cities where the number of motor vehicles is growing rapidly in the absence of lead control programs.

Some newly industrialized or advanced developing countries have converted to unleaded fuel or are in the process of phasing out lead to reduce adverse health impacts and to prevent fouling of catalytic converters. Examples include Brazil, Singapore, Malaysia, Mexico, and Thailand.

Suspended particulate matter is a major air quality problem for urban areas in developing countries. According to the World Bank, in the mid-1980s, about 1.3 billion people, mostly in developing countries, lived in towns or cities with a population of more than 250,000 that failed to meet World Health Organization standards for SPM. (World Bank 1992) SPM has been linked to respiratory problems; these problems could be exacerbated by poor health and nutrition in developing countries.

According to the World Bank, SPM levels in low-income cities increased during the 1980s, while OECD cities and middle-income cities experienced a decline. SPM levels are rising in most Asian cities, regardless of income level. (World Bank 1993, 11)

Concentrations of SO_2 were, on average, lower in low-income countries than in middle- and high-income countries in the late 1970s. As concentrations declined in the cities of the latter group of countries in the 1980s, they rose in low-income country cities. (World Bank 1995a, 44) The increase in SO_2 emissions in developing countries reflects the use of higher sulfur content fuels by the transport sector, as well as coal by industry. Twelve of the 15 cities with the highest levels of sulfur dioxide are in Asia.

Box 9-2: Urbanization and Motor Vehicle Use

Motor vehicles are concentrated in large metropolitan areas. Nearly 50 percent of automobiles in Mexico, Iran, and Thailand are located in the capital cities. About 25 percent of Brazil's vehicle fleet operates in the Sao Paulo metropolitan area; and in India, nearly one-quarter of the nation's vehicle fleet circulates in five cities (Bombay, Calcutta, Delhi, Madras and Bangalore).

Over the last two decades, populations of cities in developing countries grew faster than cities in OECD countries. Urban populations in developing countries increased from 753 million people in 1970 to 1,755 million in 1992. Still, the move to the cities is not proceeding at an equal pace everywhere: 70 percent of today's population in OECD countries and Latin America is urban, but only 35 percent in Africa and 30 percent in Asia live in cities.

Of the 16 cities with populations greater than 10 million in 1992, only four are in OECD countries: Tokyo-Yokohama, New York, Osaka, and Los Angeles. Between 1970 and 1995, the annual growth rates of these cities averaged 1.5 percent, while the growth rate of the 12 cities in non-OECD countries averaged 3.7 percent. In 1995, New Delhi, India, joined the list of mega-cities.

High density is a feature of large urban centers in developing countries. Higher densities result in greater numbers of people exposed to air pollution. In 1992, population densities of the four OECD mega-cities ranged from 9,000 people per square mile in Los Angeles to 28,000 people per square mile in the Osaka-Kobe-Kyoto metropolitan area. By contrast, the *lowest* population density among the largest cities in non-OECD countries was 22,000 people per square mile (in Buenos Aires). Population densities in the other non-OECD mega-cities ranged from 28,000 to 134,000 people per square mile.

SOURCES: A. Faiz, "Automotive Emissions in Developing Countries—Relative Implications for Global Warming, Acidification and Urban Air Quality," *Transportation Research*, vol. 27, No. 3, May 1993; and World Bank.

At the present time, CO and NO_x emissions probably pose a less immediate health hazard than lead, particulates, and sulfur oxides emissions for developing country populations, although this could change. In the early 1980s, urban CO concentrations in developing countries were similar to those in OECD countries, while urban NO_x concentrations in developing countries were slightly lower than in OECD countries. Emissions per mile of travel, however, were much higher in developing countries than in OECD countries.

► Transportation Emissions

Lack of data limits analysis of emissions trends in most non-OECD countries. (Trend data are starting to emerge from some FEB countries that now report to OECD.) Transportation in developing countries contributes more to some worldwide emissions of conventional air pollutants than their one-quarter share of vehicles might suggest. In the early 1990s, motor vehicles in non-OECD countries produced about 52 percent of worldwide CO emissions, 41 percent of VOC emissions, 36 percent of NO_x emissions, and 29 percent of CO_2 emissions. (OECD 1995c) These shares may increase in the future due to the rapid growth of motor vehicle fleets in developing countries. In fact, more recent CO_2 data already show increases.

Fossil fuel emissions from residential and industrial applications can dwarf CO emissions from the transport sector in some non-OECD countries. South Korea's relatively low percentage of CO emissions from the transportation sector in 1987 arose, in part, from low per capita car ownership. While car ownership is growing rapidly, it was still low by OECD standards in the early 1990s at 63 vehicles per 1,000 persons. (OECD 1995d, 210) South Korea tried to reduce the growth of vehicle use with the introduction of a new underground rail system in the Seoul metropolitan area, where 40 percent of South Koreans live. The system did not attract as many people as expected, however. (OECD, 1995d, 210)

The transportation sector is a significant source of VOC emissions in many non-OECD countries. Along with the lack of catalytic converters, a possible reason is vapor emissions during vehicle refueling. Although evaporative emissions can be a small percentage of total VOC emissions, the quantity is determined by the vapor pressure and composition of motor fuel and by ambient temperatures. (OECD 1993b) Motor vehicles in warmer climates tend to have higher rates of evaporative emissions. The United States and some other OECD countries have initiated various strategies, such as controls during fueling operations, to reduce evaporative emissions.

Developing countries generally use proportionally more diesel fuel than OECD countries, which can affect the nature of emissions. (World Bank 1995a, 7) Thus, while the transportation sector worldwide is not an important source of SO_2 emissions in OECD countries, the picture is different in some non-OECD countries. The reasons include higher sulfur content fuel and more diesel fuel vehicles for passenger transport. Mexico City's public transportation system, for example, has been estimated to account for 25 percent of the city's air pollution. A general trend away from high sulfur fuel is expected to reduce transportation's share of SO_2 pollution. (IEA 1995, 108)

Little data are available on lead emissions in non-OECD countries. Unleaded gasoline, however, is being phased in (see table 9-3) and the level of lead content reduced in a number of countries. As of 1993, for example, unleaded gasoline held 100 percent of the market in Brazil and South Korea and 30 percent in Mexico and China. (Tunali 1995, 126) In Russia and India, unleaded gasoline is available only in cities, as is the case in China. Many countries in the Middle East and Africa use only leaded gasoline.

► Emissions Control Efforts

Motor vehicles in developing countries tend to be older and less well maintained than in the higher income OECD countries. Vehicles are less likely to be equipped with emissions control devices. Unleaded fuels often are not available. And, vehicle fleets in developing countries tend to be less energy efficient. Further, with the higher densities of development, much less of the urban area is allocated to road space in cities of developing countries, leading to congestion and more concentrated pollution. Many developing countries do not have effective emissions control programs. Without such efforts, increased motor-vehicle emissions will expose hundreds of millions of urban dwellers to dangerously polluted air by the year 2000. (Faiz 1993)

Several newly industrialized countries and rapidly growing developing countries have begun to take action to combat air pollution. Singapore has long been one of the most active countries in addressing air pollution. Its integrated transportation policy, initiated in the early 1970s, is described in box 9-3 By 1990, other countries, including Brazil, Mexico, Chile, Hong Kong, South Korea, and Taiwan, had adopted motor vehicle emission control programs. Some other countries, such as Indonesia, Malaysia, the Philippines, and Thailand, have modest programs. (OECD 1995c, 38) Ultimately, the degree of success among these non-OECD countries will depend on a number of factors, such as the enforceability of standards, availability of unleaded fuels, and related issues such as proper maintenance for vehicles and their control devices.

Solutions to some air quality problems caused by motor vehicles may have to await further per capita income growth in developing countries. The low turnover rate of the vehicle stock in developing countries is primarily responsible for their slower fuel efficiency improvement compared with industrialized

Box 9-3: Singapore's Integrated Transportation Policy

Singapore, an island nation of 2.8 million people occupying a land area smaller than New York City, is one of the wealthiest and fastest growing economies in Asia, with a 1992 per capita income of $16,500. Since the mid-1970s, it has adopted several successively more stringent measures to mitigate congestion caused by its motor vehicle fleet, now numbering 300,000 passenger cars and 130,000 commercial vehicles.

To constrain passenger car use, Singapore has imposed extraordinarily high fees on vehicle ownership and use that would be politically unpalatable in many other countries. Duties on imported automobiles (imports account for essentially all of Singapore's cars) and vehicle registration fees were 195 percent of automobile import values in 1994; road taxes are also imposed, with the tax increasing with engine capacity. Under an area licensing scheme, first adopted in 1975 and expanded in 1989 and 1994, drivers must purchase stickers for display on windshields to access the central business district during specified hours. An electronic toll system is to be put in effect in 1996. Drivers who register their cars primarily for weekend use can get a rebate on import duties and registration fees. (These drivers can also purchase weekday use licenses for specific dates).

Singapore has an extensive public transport system, and a population density of 11,574 people per square mile. Half the population is within a kilometer of a rapid transit system. It also has invested extensively in its road infrastructure, and has computerized its traffic signal system in much of the central business district. Finally, its new settlements are planned to colocate residential, commercial, and employment centers.

For all the measures taken, demand for new vehicles among Singapore's citizens continues to be high. In 1990, a monthly quota system was imposed to limit the number of new vehicles. In the first three years of the program, the number of new vehicle registrations fell appreciably, but in 1993 exceeded the 1990 level significantly. Still, the Singapore measures have had an effect. It is estimated that Singapore's 1990 fuel consumption would have been about 40 percent higher without the constraints on automobile use.

SOURCES: Most of the information in this box is taken from Laurie Michaelis et al., "Mitigation Options in the Transportation Sector," in *Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses,* Contribution of Working Group II to the Second Annual Assessment Report of the Intergovernmental Panel on Climate Change (Cambridge, England: Cambridge University Press, in press), p. 707

countries. Low turnover also slows the addition of vehicles with catalytic converters, since they are required only for new vehicles. For example, 38 percent of Mexican vehicles were more than 10 years old in 1983; catalytic converters began to be phased in only with the 1989 model year. Half of Brazil's automobiles in 1991 were still running after 18 years, 20 percent after 24 years. For older vehicles, energy efficiency can be improved and emissions reduced through proper maintenance. A car tuning program in Pakistan led to energy savings of 5 to 6 percent. (IEA 1995, 272)

► Motorization Trends

Motorization trends will have a major influence on transportation-related air pollution in non-OECD countries. Future rates of motorization in developing countries will be affected by many factors, including population growth, economic and income growth, and urbanization patterns. Other factors, such as degree of use of nonmotorized transportation and two- or three-wheel motorized vehicles, also will play a role.

Per capita ownership of passenger cars is far lower in developing countries than in OECD countries (see table 9-4). On average, however,

TABLE 9-4: VEHICLE REGISTRATIONS AND POPULATION IN SELECTED COUNTRIES

	Total car registrations		Total commercial registrations		Annual growth rate (percent) Car	Comm. vehicles	Population	Population per car
	1970	1992	1970	1992	1970–92	1970–92	1970–92	1992
Low-income economies					9.4w	9.9w	2.3w	290w
India	609,612	2,806,533	471,722	2,396,738	7.2	7.7	2.2	316.0
Nigeria	81,000	800,000	52,000	625,000	11.0	12.0	1.3	111.0
Pakistan	172,260	731,500	50,682	213,000	6.8	6.7	0.3	166.0
China	133,000	1,900,000	480,000	4,500,000	12.8	10.7	2.0	616.0
Indonesia	238,632	1,574,806	125,552	1,513,845	9.0	12.0	2.2	124.0
Lower middle-income economies					9.6w	8.3w	2.5w	28.4w
Peru	225,700	422,262	133,718	249,223	2.9	2.9	2.4	54.0
Colombia	178,363	800,000	116,321	670,000	7.1	8.3	2.2	43.0
Algeria	142,806	4,417,882	81,625	1,552,893	16.9	14.3	4.1	7.4
Thailand	204,076	890,821	167,903	2,125,632	6.9	12.2	2.2	65.0
Turkey	147,014	2,111,354	168,949	803,496	12.9	7.3	2.4	28.0
Chile	176,066	1,007,713	149,754	206,790	8.3	1.5	1.5	13.0
Upper middle-income economies					7.2w	5.5w	2.4w	11.6w
South Africa	1,653,000	3,488,570	462,000	1,899,721	3.5	6.6	3.4	12.0
Brazil	2,234,500	12,974,991	1,305,200	1,371,127	8.3	0.2	2.3	12.0
Malaysia	279,410	2,214,974	82,623	618,137	9.9	9.6	2.5	8.3
Venezuela	614,616	1,532,572	239,084	449,135	4.2	2.9	3.2	13.0
Mexico	1,233,824	7,300,000	558,044	3,600,000	8.4	8.8	2.8	13.0
Argentina	1,563,000	4,417,882	794,000	1,552,893	4.8	3.1	1.4	7.4
South Korea	60,677	3,461,057	52,504	1,769,837	20.2	17.3	1.5	13.0
High-income economies					3.3w	4.1w	0.9w	2.1w
United Kingdom	11,792,500	23,008,342	1,910,000	3,643,398	3.1	3.0	0.2	2.5
Italy	10,209,045	29,497,000	929,363	2,763,050	4.9	5.1	0.3	2.0
Canada	6,602,176	13,322,457	1,481,197	3,688,433	3.2	4.2	1.1	2.1
France	12,290,000	24,020,000	2,114,750	5,040,000	3.1	4.0	0.6	2.4
Germany	14,376,484	39,086,000	1,228,406	2,923,000	4.7	4.0	1.4	2.1
United States	89,279,864	144,213,429	19,127,442	46,148,799	2.2	4.1	1.1	1.8
Japan	8,778,972	38,963,793	8,802,871	22,694,351	7.0	4.4	0.8	3.2

KEY: w = weighted average for all countries in income category, not just for those listed here.

SOURCES: American Automobile Manufacturers Association, *World Motor Vehicle Data* (Detroit, MI: 1971), pp. 10–11 and (Detroit, MI: 1994), pp. 25–27; and World Bank, *World Development Report 1994: Infrastructure for Development* (New York, NY: Oxford University Press, 1994); and World Bank, *World Development Report 1995: Workers in an Integrating World* (New York, NY: Oxford University Press, 1995).

the number of motor vehicles in non-OECD countries grew 6.5 percent annually, nearly twice as fast as in OECD countries, between 1970 and 1993 (see table 9-1). Some countries had much more rapid growth. Between 1987 and 1992, annual car and truck sales in Mexico more than doubled, from 246,000 to 696,000. (IEA 1995, 106) In India, the number of passenger vehicles grew more than fourfold between 1970 and 1992. Car registrations in China grew more than tenfold in the same period. (World Bank 1995a, 7)

Shifts in transportation modes can have a significant effect on overall energy efficiency and, thus, on emissions. (IEA 1995, 272) According to OECD, as countries industrialize, their vehicle mix shifts first to two- and three-wheel motorized vehicles, then to four-wheeled vehicles. Worldwide, the numbers of two- and three-wheel vehicles grew twice as fast as cars or buses from 1970 to 1990. Such vehicles consume less than 1 percent of the gasoline used in the United States, but up to 50 percent used in Taiwan, 30 percent in Thailand, and 45 percent in India. They are less popular in Latin America, consuming only 8 percent of gasoline in Bolivia and 2 percent in Brazil. One study reported that two-wheel vehicles with two-stroke engines have emissions (largely unburned gasoline) 10 times greater and fuel efficiencies 20 to 25 percent lower than four-stroke engines of equal power. (US Congress OTA 1992, 166)

Some developing country cities, such as Curitiba in Brazil, have adopted innovative ways of meeting their transportation needs through public transportation (see box 9-4). Another counterweight in developing countries to ever-increasing motor vehicle fleets is, as discussed in box 9-5, to enhance and encourage nonmotorized transportation, where appropriate. Nonmotorized goods transport is still important in developing countries, especially in rural areas.

Growth of Road Networks

Road networks in developing countries are also growing. Between 1970 and 1992, the growth rate of paved road ranged between 2 and 12 percent in developing countries, but less than 2.5 percent in high-income countries (except for Japan, which had a growth rate of nearly 8 percent). (World Bank 1994 and 1995c)

Road networks in developing countries are still far less dense than in the United States, Canada, Europe, and Japan. Paved road density in 1992 in these latter countries was many times higher than in even upper middle-income developing countries. The large gap between road densities in developed and developing countries suggests a potential for continued increase in road density in developing countries.

Given the very high population densities in the cities of developing countries, often much less of the urban area is allocated to road space than was true of western cities during the early phase of motorization. When New York City was at its most dense in terms of population per square mile in 1910, roads made up 15 percent of the urban land area of Manhattan. The corresponding figure for road space in Chinese cities today is often less than 10 percent. (Grakenheinor 1994)

Transportation and Greenhouse Gases

In 1990, the world's transportation sector was responsible for almost one-fifth of total world CO_2 emissions. Table 9-5 shows the 20 countries in the world that consumed the most transportation fuel (and thus produced the most CO_2 emissions from transportation) in 1990. (Michaelis et al 1996) The United States tops

BOX 9-4: A SURFACE SUBWAY: CURITIBA, BRAZIL

Curitiba, a city of 1.6 million people in southern Brazil, illustrates one way to manage the damaging environmental effects of rapid population and transportation growth. To cope with the transportation needs of a population that tripled in a little over 20 years, Curitiba built a highly accessible, fast, and relatively inexpensive bus system. The buses are widely used: in 1993, they carried 1.5 million passengers a day, more than ride buses in New York City and four times the number that ride the subway in Rio de Janeiro, a city of 10 million. Although Curitiba has the second highest rate of car ownership in Brazil (33 automobiles per 100 people), 75 percent of its commuters use buses daily compared with 57 percent in Rio and 45 percent in Sao Paulo. Partly as a result, Curitiba's per capita gasoline consumption is 30 percent lower than in eight comparable Brazilian cities.

When developing its bus system in the early 1970s, the city bought or condemned land along five transportation radials that converge on the city center. Each radial is surrounded by a two to four block corridor that is zoned for high-density, low-income housing. Bus lanes were constructed in the median of each radial. Express buses use the lanes to shuttle people downtown or to factories on the urban fringe. Other buses continually loop through the less densely developed neighborhoods to take people to the express bus terminals. Another set of buses travel between outlying districts allowing passengers to travel between them without passing through the center. To speed loading and unloading, tubular bus shelters have been installed. People pay before the bus arrives and board through sliding glass doors synchronized with those on the bus. Some of the busiest routes are now served by three-car buses able to carry 270 passengers. Because of these features, some have called the system a "surface subway," although city officials like to point out that it cost approximately one three-hundredth of a subway system and can be constructed in a fraction of the time. The system is supported by passenger fares. Buses are owned and operated by private companies but regulated by city government, which sets fares, assigns routes, and pays each contractor by the number of passengers carried and kilometers traveled. Fares also cover the cost of road and terminal construction and maintenance and system planning by the city.

SOURCES: Kris Herbst, "Brazil's Model City: Is Curitiba Too Good to be True?" *Planning*, September 1992, pp. 24–27; and Todd Lewan, "Curitiba, Brazil: Model Metropolis Greens as it Grows," *Safety and Health*, April 1994, pp. 44–48.

the list; its transportation energy use is equal to that of the next 10 countries combined. Developing and FEB countries comprise half the countries on the list.[7]

The *Transportation Statistics Annual Report 1995* comprehensively reviewed the status of transportation's contribution to greenhouse gases, as represented by CO_2 emissions. (USDOT BTS 1995, 65-82) The review, over the period 1965 to 1992, compared U.S. data with that of six other OECD countries: Canada, western Germany, France, the United Kingdom, Japan, and Italy. Because CO_2 emissions are directly related to the amount and intensity of energy use, the report also discussed the many factors that drive transportation energy use in these countries. Among those factors are: the increasing magnitude and evolving modal composition of passenger and freight flows, the changing energy intensity of different transportation modes, the shifting vehicle mix in road transportation, the increasing personal propensity for travel, and changing vehicle occupancy rates and load factors.

[7] As noted earlier, Mexico is included in the non-OECD countries. OECD statistics included here have been adjusted to reflect that division.

Box 9-5: Nonmotorized Transportation

Nonmotorized transportation, including bicycles, rickshaws, and walking, remains the most important form of mobility in many developing countries. Beijing, China, residents, for example, in the early 1990s owned 400,000 motor vehicles but 7 million bicycles. In Guangzhou, China in 1989, two-thirds of trips were made by nonmotorized transportation—36 percent by walking and 30 percent by bicycle—and only one-third by motor vehicles including buses, vans, ferry boats, private automobiles, taxis, and motorcycles. In large African cities such as Kinshasa and Dar es Salaam, two-thirds of total trips are made on foot. In Delhi, India, 29 percent of trips were made by walking and 18 percent by bicycle in the early 1980s. Nonmotorized transportation is not merely for personal travel. It has been estimated that cycle rickshaws account for 10 to 20 percent of urban freight movement in many Asian cities. In Bangladesh nonmotorized vehicles accounted for 36 percent of freight ton-miles in 1985.

Nonmotorized transportation is cheap, efficient for relatively short distances, and has very little impact on the environment. In many places, particularly those with rising income levels, conflicts between nonmotorized and motorized modes are becoming increasingly pronounced. The greater use of motor vehicles, especially automobiles, results in less street space for cyclists and pedestrians, greater danger, and over time changes in urban form rendering nonmotorized modes less viable. In Guangzhou, where the number of motor vehicles increased tenfold between 1980 and 1990 it is thought that some have switched to motor vehicles because of the increased danger associated with cycling and walking.

Government policies have generally encouraged motorization and in some cases actively discouraged nonmotorized options, often seen as backward, inefficient, unsafe, and the cause of traffic congestion. The city government in Jakarta, Indonesia, for example, confiscated and destroyed over 100,000 cycle rickshaws in the 1980s in an attempt to eliminate them from the city. Dacca, Bangladesh, in the late 1980s banned pedicabs from the city because of safety problems. In 1995, Calcutta announced plans to ban human-pulled rickshaws.

Following the example of developed western countries, governments in less developed countries, often supported by the World Bank, have provided subsidies and capital investments to support motorization. More recently, however, the World Bank has begun to reformulate its policies toward more sustainable transportation options including mass transportation and nonmotorized modes. In Accra, Ghana, for example, the World Bank is sponsoring the construction of dedicated cycle paths to connect neighborhoods with commercial districts. In other places there is a growing view that to focus purely on motorization will damage mobility by creating untenable levels of congestion, hence the need for balancing and intergrating both motorized and nonmotorized transportation. In Chinese cities, for example, to reduce the conflict between motorized and nonmotorized modes, planners have suggested better traffic control measures, the separation of modes, perhaps with bicycle-only roads, and the better integration of nonmotorized modes with mass transportation.

SOURCES: John F. Burns, "A Tradition Facing the End of the Road: Striving for a More Upscale Image, Calcutta's Officials Target Rickshaws," *New York Times*, Oct. 4, 1995, p. A4.

C. Jones, "To Spiff Up Its Image, Jakarta Does Away with Traditional Taxis: Officials Say Three-Wheelers are an Eyesore in Indonesian Capital," *Christian Science Monitor*, Aug. 19, 1988.

William H.K. Lam et al., "Urban Transportation Planning and Traffic Management in China," *Transportation Research Record No. 1372*, 1992, pp. 11–17.

V. Setty Pendakur, "Urban Transportation in China: Trends and Issues," *Transportation Research Record No. 1372*, 1992, pp. 3–10.

Michael Replogle, "Bicycles and Cycle-Rickshaws in Asian Cities: Issues and Strategies," *Transportation Research Record No. 1372*, 1992, pp. 76–84.

Michael Replogle, "Sustainable Transportation Strategies for Third World Development," *Transportation Research Record No. 1294*, 1991, pp. 1–8.

Carol Thomas et al.). "Policy Implications of Increasing Motorization for Nonmotorized Transportation in Developing Countries: Guangzhou, People's Republic of China," *Transportation Research Record No. 1372*, 1992, pp. 18–25.

World Bank, *Mainstreaming the Environment: The World Bank Group and the Environment Since the Rio Earth Summit* (Washington, DC: 1995).

Table 9-5: CO_2 Emissions from Transportation Energy Use in Selected Countries, 1990

	Exajoules[a]	Carbon dioxide (million metric tons, estimated)
United States	20.3	1,523
Russia	3.5	263
Japan	3.2	240
Germany	2.5	188
United Kingdom	1.9	143
France	1.7	128
Canada	1.7	128
China	1.7	128
Italy	1.5	113
Brazil	1.4	105
Mexico	1.3	98
India	1.1	83
Spain	1.0	75
Australia	0.9	68
Ukraine	0.7	53
South Korea	0.6	45
Thailand	0.5	38
South Africa	0.5	38
Netherlands	0.4	30
Indonesia	0.4	30
Rest of world	7.9	593
TOTAL	54.7	4,103

[a]Includes transport fuel sales, excluding marine bunkers.
[b]Converted at 75 million metric tons carbon dioxide per exajoule.

SOURCE: Laurie Michaelis et al., "Mitigation Options in the Transportation Sector," in *Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses,* Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change (Cambridge, England: Cambridge University Press, in press), p. 683.

Because adequate data on transportation energy use were not available, CO_2 emissions by non-OECD countries were not included in last year's analysis. The two sections that follow recap and update, where possible, last year's discussion on OECD countries and provide data and information on non-OECD countries. This year the discussion is centered on the period 1971 to 1993, allowing for comparison across these two sets of countries.

Greenhouse gas emissions in OECD countries are primarily related to energy use. In developing countries, by contrast, emissions have been tied to changes in land use (e.g., deforestation). As noted earlier, however, motor vehicle use is increasing dramatically in many non-OECD countries, as is industrial use of energy. Developing countries (including Mexico) accounted for 52 percent of all forms of CO_2 emissions in 1992, compared with 45 percent in 1980. (On a per capita basis, however, energy use is far higher in OECD countries).

The picture is quite different when only CO_2 emissions from transportation are considered. In 1993, OECD countries produced 65 percent of CO_2 emissions related to transportation; non-OECD countries, 35 percent (see table 9-6). Transportation produced 28 percent of OECD's CO_2 emissions in 1993 but only 14 percent within non-OECD countries. The energy and industrial sectors in non-OECD countries in 1993 emitted more tons of CO_2 (6,936 million metric tons) than did the same sectors of OECD countries (5,826 million metric tons).

Conventional automotive technology cannot reduce emissions of CO_2—a necessary byproduct of fossil fuel combustion—except by improvements in fuel efficiency or the use of alternative fuels. (See chapter 4 for further discussion of alternative fuels.)

► OECD and CO_2 Emissions

The factors contributing to CO_2 emissions from transportation are complex and interrelated. *Transportation Statistics Annual Report 1995*, in comparing the United States with selected other OECD countries, found a growing convergence among the OECD countries as

TABLE 9-6: MOBILE SOURCE CO_2 EMISSIONS BY REGION, 1971–93 (MILLION METRIC TONS)

	1971	1980	1993	World total (percent) 1971	World total (percent) 1993
United States	1,079.7	1,251.4	1,489.8	39	34
Canada	88.1	129.6	129.9	3	3
OECD-Europe	575.8	611.3	873.8	21	20
Japan	150.2	160.3	244.1	5	6
Australia/New Zealand	46.2	59.0	79.1	2	2
OECD total	**1,940**	**2,211.5**	**2,816.7**	**70**	**65**
Non-OECD Europe	79.9	86.5	68.2	3	2
Former Soviet Union	276.9	351.8	298.8	10	6
Asia	141	166.0	365.9	5	9
China	[a]	83.1	168.1	—	3
Latin America[b]	200.7	260.9	340.3	7	8
Africa	45.8	91.5	117.6	2	3
Middle East	105.3	88.8	158.4	4	4
Non-OECD total	**849.6**	**1,128.6**	**1,517.3**	**30**	**35**
Non-OECD without Europe and former Soviet Union	492.8	690.3	1,150.3	18	27
World total	2,789.6	3,340.1	4,334.0	100	100

[a] Data not available for 1971.
[b] Data for Mexico is included in non-OECD Latin America.

SOURCE: Organization for Economic Cooperation and Development, *OECD Environmental Data: Compendium 1993* (Paris, France: 1993), p. 33, and *OECD Environmental Data: Compendium 1995* (Paris, France: 1995), p. 41 (revised); and personal communication.

the differences between per capita GDPs, in terms of purchasing power parities, decreased.

Among OECD countries, transportation energy use and CO_2 emissions grew faster than total energy use and total CO_2 emissions. This is also true on a per capita basis, although rates of growth differ. In France, transportation's share of total CO_2 emissions per capita doubled between 1965 and 1992, as did the United Kingdom's. France had the highest per capita emissions by 1992. Transportation's share of CO_2 emissions in the United States and Canada grew at a slower rate.

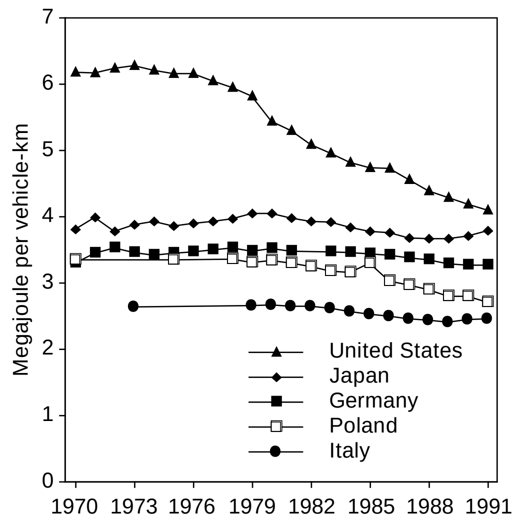
As incomes have risen in OECD countries, so has car ownership and propensity to travel. The mean annual per capita travel of European OECD countries moved from about one-third of the U.S. levels in 1965 to about one-half by 1992. The United States still has higher income, car ownership, and per capita travel than other OECD countries, explaining in part, the much higher per capita transportation energy consumption and CO_2 emissions of the United States.

OECD also found a relationship between prices of fuel and vehicle efficiencies and miles driven. Italy, for example, has the highest fuel taxes and gasoline prices and most fuel-efficient stock of cars in the European Union (8.4 liters of gasoline per 100 kilometers, or 28 miles per gallon). The United States, which has the least expensive fuel among OECD countries, averages 30 percent more vehicle-kilometers per capita annually than Germany, the Netherlands, and France, and 70 percent more than Italy. (IEA 1995, 125) The differences in fuel costs largely reflect different tax policies. For example, French gasoline taxes in 1993 were more than seven times higher than those in the United States. (IEA 1995, 86)

As figure 9-3 shows, the average fuel consumption of passenger cars in the United States improved significantly in the last two decades. During the same period, the averages in Japan and Germany showed only minor changes. Today, the once wide gap between fuel efficiency of U.S. and European cars has narrowed considerably. CO_2 emissions from transportation would be considerably higher today in the United States if there had not been such an improvement in automotive fuel efficiency.

The shift from rail and water transport to air and road transport in OECD countries increased CO_2 emissions from transportation. Steeper increases were observed in Japan and European OECD countries than in the United States. In the last decade, the United States has had one of the lowest growths in CO_2 emissions from mobile sources (19 percent) within OECD and in comparison with non-OECD countries.

FIGURE 9-3: LIGHT-DUTY PASSENGER-VEHICLE ENERGY INTENSITY



SOURCE: Laurie Michaelis et al., "Mitigation Options in the Transportation Sector," in *Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses,* Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change (Cambridge, England: Cambridge University Press, in press), p. 683.

▶ CO_2 Emissions and Non-OECD Countries

Over the past two decades, much of the growth in worldwide CO_2 emissions occurred in non-OECD countries, such as China, Brazil, India, and South Korea. Rapid economic growth and associated increases in energy use occurred in many non-OECD countries. Between 1970 and 1992, CO_2 emissions from energy use in developing countries grew 89 percent. In contrast, OECD energy use emissions increased by 15 percent during the same period. Around 1984, developing countries surpassed OECD countries in the release of CO_2 emissions from energy use.

While non-OECD countries increased their share of total emissions of CO_2, their share of the world's mobile source CO_2 emissions remained at about 30 percent until recently. By 1993, the non-OECD countries' share of mobile source emissions had risen to 35 percent. Between 1971 and 1993, mobile source CO_2 emissions in these countries increased 79 percent. Over the same period, OECD countries' emissions grew 45 percent.

The growth in non-OECD CO_2 emissions is even more pronounced if the FEB economies are not considered. The FEB countries experienced such severe economic setbacks beginning in the 1980s that CO_2 emissions from transportation fell 21 percent in Eastern Europe and

15 percent in the former Soviet Union over the period 1980 to 1993. Thus, if FEB data are excluded, the remaining non-OECD countries' transportation-related CO_2 emissions grew 67 percent from 1980 to 1993.

While FEB countries have, in the past, relied more heavily on rail transport, there has been a significant shift toward less efficient road travel. Passenger rail in 1993 was down almost 43 percent from 1989, partly because of a fall in incomes and partly because of greater competition from private cars. Freight traffic by rail also declined in favor of road transport. (OECD 1994a, 67)

Africa is the region of the world that makes the smallest contribution (3 percent) to transportation-related CO_2 emissions. From 1971 to 1993, however, the region's mobile source emissions grew by 157 percent. Future emissions will be tied to economic growth. Research covering nine nations in eastern Africa found that the transportation sector consumes only 5 percent of total energy use, resulting in 9 million metric tons of CO_2 emissions in 1990. (Mackenzie et al. 1992) Two of the countries, Uganda and the Seychelles, experienced annual GNP growth rates over 3 percent; the balance have negative or near zero growth rates.

Transportation fleets in developing countries tend to use energy less efficiently, releasing more CO_2 per unit of output. (Chatterjee and Han 1994) IEA estimates specific fuel consumption in non-OECD countries to be nearly 30 percent higher than the OECD average. Several factors explain this inefficiency: the average vehicle is old and poorly maintained, cities are congested, and the transportation infrastructure is poor. (IEA 1995, 274) Problems differ across regions, however. Vehicles tend to be less energy intensive in Asia than in Latin America and Africa. Car and engine size are smaller in India, China, and South Korea than in Venezuela.

References

Chatterjee, L. and X. Han. 1994. Factors Underlying Changes in the CO_2 Emissions of Selected Countries, report of a research project sponsored by the U.S. Department of Energy.

Faiz, A. 1993. Automotive Emissions in Developing Countries—Relative Implications for Global Warming, Acidification and Urban Air Quality. *Transportation Research* 27: 3. May.

Grakenheinor, R. 1994. Six Strategic Decisions for Transportation in Megacities. *Megacity Growth and the Future.* Edited by R.J. Fuchs, E. Brennon, J. Chamie, F. Lo, and J.I. Vitto. New York, NY: U.N. University Press.

International Energy Agency (IEA). 1995. *World Energy Outlook 1995*. Paris, France.

Michaelis, Laurie, D. Bleviss, J.-P. Orfeuil, and R. Pischinger. 1996. Mitigation Options in the Transportation Sector. *Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analysis*, Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change. Edited by R.T. Watson, M.C. Zinyowera, and R.H. Moss. Cambridge, England: Cambridge University Press.

Mackenzie, Gordon et al. 1992. Transport Sector of Eastern Africa: Environment Related Responses. Draft.

Organization for Economic Cooperation and Development (OECD). 1993a. *OECD Environmental Data: Compendium 1993.* Paris, France.

_____. 1993b. Evaporative Emissions for Motor Vehicles and Refueling Systems, Environment Monographs, No. 56.

_____. European Conference of Ministers of Transport. 1994a. *41st Annual Report.* Paris, France.

______. 1994b. *Environmental Performance Reviews: Japan.* Paris, France.

______. 1995a. *Control of Hazardous Air Pollutants in OECD Countries.* Paris, France.

______. 1995b. *OECD Environmental Data: Compendium 1995.* Paris, France.

______. 1995c. *Motor Vehicle Pollution: Reduction Strategies Beyond 2010.* Paris, France.

______. European Conference of Ministers of Transport. 1995d. *Urban Travel and Sustainable Development.* Paris, France.

Tunali, O. 1995. Lead in Gasoline Slowly Phased Out. *Vital Signs 1995: The Trends that are Shaping our Future.* New York, NY: W.W. Norton.

U.S. Congress, Office of Technology Assessment (OTA). 1992. *Fueling Development: Energy Technologies for Developing Countries*. Washington, DC: U.S. Government Printing Office. April.

______. 1993. *Energy Efficient Technology for Central and Eastern Europe.* Washington: DC: U.S. Government Printing Office. May.

U.S. Department of Energy (USDOE), Energy Information Administration (EIA). 1994. *Energy Use and Carbon Emissions: Some International Comparisons.* Washington, DC. March.

U.S. Environmental Protection Agency (USEPA), Office of Air Quality. 1995. *National Air Pollutant Emission Trends, 1990–1994,* EPA 454/R-95-011. Research Triangle Park, NC. October.

U.S. Department of Transportation (USDOT), Bureau of Transportation Statistics (BTS). 1995. *Transportation Statistics Annual Report 1995.* Washington, DC. November.

World Bank. 1992. *The World Development Report 1992: Development and the Environment.* New York, NY: Oxford University Press.

______. 1993. *Toward an Environmental Strategy for Asia.* Washington, DC.

______. 1994. *The World Development Report 1994*. New York, NY: Oxford University Press. June.

______. 1995a. *Air Quality Management: Considerations for Developing Countries.* Washington, DC.

______. 1995b. *The World Bank Atlas 1996.* Washington, DC.

______. 1995c. *The World Development Report 1995*. New York, NY: Oxford University Press. June.